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Low-Intensity Resistance Training and Compression Garment in the Management of Breast Cancer–Related Lymphedema: Single-Blinded Randomized Controlled Trial

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Abstract

There is limited evidence regarding the combined effect of exercise and compression garment on breast cancer–related lymphedema (BCRL). Therefore, we investigate the effect of low-intensity resistance training alone or in combination with a compression garment on lymphedema volume, self-reported lymphedema symptoms, and shoulder mobility and function. A total of 60 women with unilateral BCRL were randomly assigned to low-intensity resistance exercises (Rex group, $n = 30$) or exercises and compression garment (Rex-Com-group, $n = 30$). Both groups take part in exercises program consisted of 10–12 repetitions at 50 to 60% of one repetition maximum (IRM), three times weekly, for 8 weeks. The primary outcome was lymphedema volume determined by percentage reduction of excess limb volume (ELV). Secondary outcomes were lymphedema symptoms (pain, heaviness, and tightness) and shoulder mobility and function using the disabilities of the arm, shoulder, and hand (DASH) questionnaire. All measurements were standardized and performed before (week 0, W0), after the intervention (week 8, W8), and at follow-up (week 12, W12). A significant reduction in percentage of ELV ($p < 0.01$), pain severity ($p < 0.05$), a sensation of heaviness ($p < 0.05$) and tightness ($p < 0.001$), and improvement in shoulder range of motion ($p < 0.05$) and function on DASH scores ($p < 0.05$) were observed at W8 and W12 in both groups. However, no between-group differences were observed over time. These findings suggest that low-intensity resistance training, irrespective of garment use, can effectively reduce limb volume and lymphedema symptoms, and increase shoulder mobility and function.

Keywords Breast cancer · Lymphedema · Low-intensity exercises

Introduction

Breast cancer–related lymphedema (BCRL) is one of the most common complications reported following breast surgeries and its treatment [1]. BCRL is a chronic condition characterized by the accumulation of fluid in subcutaneous tissues that may progress in severity over time from mild swelling to severe edema with adipose tissue fibrosis causing hardening of the affected limb [2, 3]. The incidence of BCRL is varying from 3 to 65% [4I] depending on methods of lymphedema definition, assessment and diagnosis, therapeutic and surgical interventions, and length of follow-up [1, 4–6]. Survival with BCRL may be experienced with substantial pain, feeling of heaviness and discomfort, limited shoulder mobility, muscular weakness, and increased risk of infection [1, 5, 7]. These are leading to functional impairments, activity limitations, and participation restrictions, with subsequent psychosocial distress and poor quality of life [1, 8, 9].

There are numerous physical therapy interventions effective in treating BCRL, including complete decongestive therapy [10], low-level laser therapy [11], exercise, and compression garment [12–14]. Both exercise training and compression garment are an essential component in the BCRL throughout rehabilitation processes. However, early clinical recommendations showed that women with or at risk of BCRL should limit their physical activity and avoid strenuous exercises as it

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might induce or exacerbate lymphedema [15, 16]. This advice aimed to prevent and/or minimize the risk of injury and lymphedema development. However, this advice causes limited physical activity and deconditioning, decline of muscle strength and function of the affected limb, and reduced quality of life [17, 18].

In contrast, recent findings from preliminary researches found no association between lymphedema and exercises training [19–24]. Recent systematic reviews [25–29] found that resistance exercises training do not increase the risk of lymphedema nor exacerbate the symptoms, and reduces upper limb morbidity and improves physical function and quality of life [28].

The role of compression garments during exercise is unclear. Recent systematic reviews and clinical trials do not provide adequate evidence and cannot support positive and negative effects of compression garment use during exercise [30–35]. Compression garment may be used to prevent or treat lymphedema through exerting one or more of the following effects: (1) increasing interstitial pressure, (2) augmenting tissue fluid drainage, (3) stimulating lymphatic contractions, (4) enhancing muscle pumping effectiveness, and (5) breaking down fibrosclerotic tissue [36]. Furthermore, the National Lymphedema Network (NLN) supports the use of the compression garment during exercise in patients with BCRL [36]. Therefore, the purpose of this study was to investigate the effect of exercise alone or when combined with a compression garment on limb volume, self-reported lymphedema symptoms, and shoulder mobility and function in women with BCRL.

Methods

Participants

This was a blinded randomized controlled clinical trial. Participants were recruited from the outpatient clinic at the National Cancer Institute and El-Mattaria Teaching Hospital, Cairo, Egypt. Medical oncologists and surgeons referred all participants during follow-up visits and the primary researcher screened them for eligibility. A participant who fulfilled the inclusion criteria and accepted to take part in the study signed informed consent is included.

The inclusion criteria were (1) women ≥18 years old and (2) unilateral BCRL ≥ 5% of inter-limb differences of volume or circumference [37]. Participants were excluded if they had (1) bilateral BCRL; (2) current metastases, continuing radiotherapy, cellulite, venous thrombosis, infection, and congestive heart failure; (3) paralysis and severe trauma; (4) previous lymphedema therapy within the last 3 months; (4) required medication that might affect body fluid and electrolyte balance; and (5) participated in an exercise program (defined as 1 h of moderate intensity exercise performed three times per week) during the last month.

The study protocol was approved by the local research ethics committee at EL-Mattaria Teaching Hospital. The trial has been registered in the Pan African Clinical Trial Registry (PACTR201802003078232).

Randomization and Sample Size

A blinded therapist not involved in the trial completed the randomization using computer-generated random numbers and canceled in a sealed envelope prior to baseline assessment. Participants were allocated using a 1:1 ratio to assign in either resistance exercises with compression therapy group (Rex-Comp group) or resistance exercise alone group (Rex group) alone. The sample size calculations were based on differences in the primary outcome (lymphedema volume), with a 5% change being clinically significant with an effect size of 0.4 and power = 0.8, at the significance level of 0.05; the estimated sample size was 62 participants in both groups. For a possible drop out of 10%, the number increased to 68 participants [24].

Outcome Measurements

A blinded therapist unaware of treatment allocation collected information about demographic and clinical characteristics from direct interviews and medical records. The outcome measures included lymphedema volume, self-reported lymphedema symptoms, shoulder mobility and function, and adherence rate. All these outcomes were assessed at baseline (W0), after the end of treatment at week eight (W8), and at the follow-up visit (W12).

Limb Volume Measurement

Limb volume was assessed by circumference measurements using a non-elastic tape. The participants were instructed to seat with arm resting on a table in 90 degrees abduction during the measurement process. Then, the circumference was taken at the levels of metacarpal and wrist, and at 4-cm intervals up the arm until the base of the axilla for both affected and unaffected limbs. A mean of two measurements was taken, but if the difference is ≥ 10% was observed between these two measurements, a third measurement was performed. The limb volume was calculated based on the frustum formula [38], and the excess limb volume (ELV) and percentage of ELV were calculated. Changes in lymphedema volume were calculated as a relative percentage of change in ELV volume (% reduction ELV) based on the previous work [21] as following:

$$\text{Percent of relative change in ELV} = \frac{(\text{ELV time1} - \text{ELV time2}) \times 100}{\text{ELVtime 1}}$$

Self-Reported Lymphedema Symptoms

The women were instructed to rate their pain severity, feeling of tightness, and heaviness using a 10-cm horizontal line of the visual analogue scale (VAS), where "zero" shows that the symptoms are not present, while "10" is the worst imaginable experience of those symptoms. The VAS is a validated and effective method to test pain; furthermore, it is adapted in lymphedema trials to assess sensations specific to lymphedema [31–33].

Shoulder Mobility and Function

For the measurement of active shoulder range of motion (ROM), the women assumed the supine position while the thorax firmly strapped to the table and knees bent and feet steady on a bench to prevent the body shift, which would compensate shoulder movement. A goniometer was used to determine the angles of maximum abduction, flexion (elevation), and external rotation. The details of the test procedures were described in our previous work [39]. From previous studies, the test–retest reliability of the goniometer to assess shoulder mobility is high, (0.83–0.97) [40]. Inter-limb differences in a range of motion of ≥ 25° were defined as impaired shoulder mobility [41].

Assessment of the upper limb function was performed using the Arabic version of the disabilities of the arm, shoulder, and hand (DASH) questionnaire. The Arabic version of DASH has an excellent internal consistency ($r = 0.94$) and test–retest reliability ($r = 0.97$) [42]. The Oncology Section of the American Physical Therapy Association in the Evaluation Database to Guide Effectiveness (EDGE) highly recommended the use of DASH with lymphedema due to breast cancer because of its clinical utility and excellent psychometric properties [43]. The questionnaire has 30 core items: 21 items about physical function, five items about symptoms, and four items about social and occupational function. Each item is scored on a five-point Likert scale from 1 "no difficulty or no symptom" to 5 "unable to perform the activity or very severe symptom"; the final scores range from 0 to 100% where "0" means no disability (good function) and "100" is a severe disability (poor function) [44].

Adherence to Exercises and Compression Garment

Adherence to exercises was obtained from exercise logs completed by the therapist who supervised the exercises. It was defined as the number of supervised exercise sessions attended, divided by the number of supervised exercise sessions offered with high adherence attendance of at least 80% of the sessions [45, 46]. Adherence to garment used was assessed through self-reported daily about how frequently (on average) they used the compression garment. The participant was considered adherent if the garment was worn > 3 times per week for the most waking hour ≥ 12 h [21].

Intervention

Women in both groups were instructed to perform resistance exercises three times weekly for 8 weeks. The training sessions consist of warm-up and cool-down periods (movement of large joint 10–15 repetitions and active stretching exercise for 15 min), and resistance training program. This program is designed and modified from previous studies [22, 24, 32, 47–51], and target the shoulder muscles, and movements are at risk in BCRL. Active stretching exercises were performed in supine and included (i) shoulder flexion, (ii) horizontal extension at 135 degrees abduction, and (iii) horizontal extension at 90 degrees abduction. The patient actively sustained and maintained each exercise for 5 min [47, 48]. The exercise interventionist (physiotherapist) supervised the exercises in both groups and provided information about compression garment.

The prescribed exercises were performed using free weight dumbbells as following: (1) dumbbell fly, (2) triceps extension, (3) biceps curl up, (4) one-arm bent over row, (5) dumbbell sides rise, (6) lifting the arm forward, (7) and wrist curl [32, 50]. The exercises were performed at 50 to 60% of their estimated one repetition maximum (IRM), with two sets of 10–12 repetitions for each exercise, with 2-min rest between each set and exercise. The exercises were repeated with a gradual increase in resistance weight by 5–10% when women completed three sets of 12 repetitions with no complaints in arms [49].

Similar to previous work, the participants in the Rex-Comp group were instructed to wear their compression garment during the supervised exercises sessions, depending on their personal preferences [24]. A booklet was provided to self-report if the women tolerated and wore garment regularly. The therapist advised the participants to maintain their lymphedema self-care, activities of daily living, and dietary habits as usual through the treatment period.

Statistical Analysis

Data were analyzed using the Statistical Package of Social Sciences (SPSS) for Windows version 21.0 (IBM SPSS, Chicago, IL), and an alpha level of 0.05 was considered significant. Missing data were not included in the analysis. Baseline demographic and clinical characteristics were reported descriptively as mean and standard deviation for normally distributed data, and number and frequency for categorical

data, while comparative analysis was made by using an independent samples *t* test for continuous data and chi-square analysis for categorical data.

Between groups, compressions for the primary and secondary outcome at each time were performed using the unpaired *t* test and chi-square test. For within-group comparison, the Wilcoxon test was used to determine the changes in the general symptoms of lymphedema (pain, tenderness, and heaviness). Analysis of variance with the baseline measurement as a covariate (ANCOVA) and an interaction in the term of (groups × times) were used, and the Bonferroni post hoc test was made for comparisons for multiple testing to identify differences in outcome variables.

Results

Participation Characteristics

Figure 1 shows the participants flow through the intervention and data collection to final analysis and reasons for withdrawal. Eighty-two participants were screened. Of these, 74 were enrolled and only 70 participants completed baseline assessment (W0) and randomized to Rex-Comp group ($n = 35$) and Rex group ($n = 35$). After randomization, five women declined to take part in the study and 65 participants completed the interventions and assessment at week 8 (W8). Only 60 participants returned for the follow-up assessment (W12): Rex-Comp group ($n = 30$) and Rex group ($n = 30$) were included for analysis

Table 1 summarizes the baseline demographic and clinical characteristics of participants. The two groups were balanced for all major baseline demographic and clinical characteristics. 71.67% participants ($n = 43$) had stage I lymphedema. Regarding the severity of lymphedema, most of the participants 63.33% ($n = 38$) had mild lymphedema, 36.67% of the participants ($n = 22$) had moderate lymphedema, and no participant had severe lymphedema.

Lymphedema Volume Reduction

Table 2 represents the comparison of changes in lymphedema volume at baseline (W0) after the end of treatment (W8) and at follow-up (W12). No significant differences existed between groups at baseline (W0) for the extent of the swelling as assessed by ELV ($p > 0.05$), and %ELV ($p > 0.05$).

At the end of treatment (W8), the excess limb volume and percentage of ELV decreased significantly in both groups (Rex group 434.99 ± 121.27 and 18.71 ± 5.01; Rex-Comp group 437.12 ± 170.92 and 18.99 ± 8.15). The relative volume (% reduction ELV) showed statistically significant changes for both groups. (Rex-Comp group 10.77 ± 7.36; Rex group 9.37 ± 4.54). These reductions were sustained to follow-up (W12), in both the Rex-Com group (12.89 ± 8.23; $p = 0.03$) and the Rex group (10.61 ± 3.54; $p = 0.23$), but did not reach a statistical significance compared with the changes at the end of treatment (W8). No statistically significant changes in the relative volume (% reduction ELV) was observed between groups at the end of treatment (W8) ($\boldsymbol{p} > 0.05$) or at follow-up (W12) ($\boldsymbol{p} > 0.05$).

Self-Reported Lymphedema Symptoms

Table 3 represents the comparison of changes in self-reported lymphedema symptoms on VAS. There were no significant differences in self-reported lymphedema symptoms (pain $p = 0.45$, heaviness $p = 0.65$, and tightness $p = 0.35$), whereby, 56.67% ($n = 34$) of the participants experienced pain (Rex-Comp group ($n = 18$); Rex group ($n = 16$)), 68.33% ($n = 41$) of the participants had heaviness (Rex-Comp group ($n = 21$); Rex group ($n = 20$)), and 58.33% ($n = 35$) of the participants experienced tightness (Rex-Comp group ($n = 19$); and Rex group ($n = 16$)).

At the end of treatment (W8), participants in both groups reported having experienced lower pain (Rex-Com group, $p = 0.02$; Rex group, $p = 0.04$), heaviness (Rex-Com group, $p = 0.003$; Rex group, $p = 0.006$), and tightness ($p = 0.001$). These reductions were sustained in both groups at the follow-up assessment (W12), but not statistically significant compared to week 8. There were no differences between the groups concerning any self-reported symptoms at the end of treatment (W8) or at follow-up (W12).

Shoulder Mobility and Function

Table 3 represents the measurement of physical function including the shoulder active ROM and DASH over time in both groups. No significant differences were observed between groups in shoulder mobility (flexion $p > 0.05$; abduction $p > 0.05$; external rotation $p > 0.05$) and function as assessed by DASH ($p = 0.53$) at baseline (W0). However, impaired shoulder mobility (inter-limb differences in ROM ≥ 25 degrees) was reported in 60% ($n = 36$) of the participants (Rex-Com group ($n = 20$) and Rex group ($n = 16$)). Shoulder flexion, abduction, and external rotation movements were increased at the end of treatment (W8) in both groups. This improvement was sustained to follow-up (W12) ($p < 0.05$). However, there were no significant differences in shoulder flexion ($p = 0.56$, $p = 0.58$), abduction ($p = 0.53$, $p = 0.94$), and external rotation ($p = 0.63$, $p = 0.46$) between groups at the end of treatment (W8) and at follow-up (W12), respectively.

Shoulder functions were significantly increased as assessed by DASH scores at the end of the treatment (W8) and at follow-up (W12) ($p < 0.05$). This improvement in physical function was sustained at follow-up (W12), However, it was

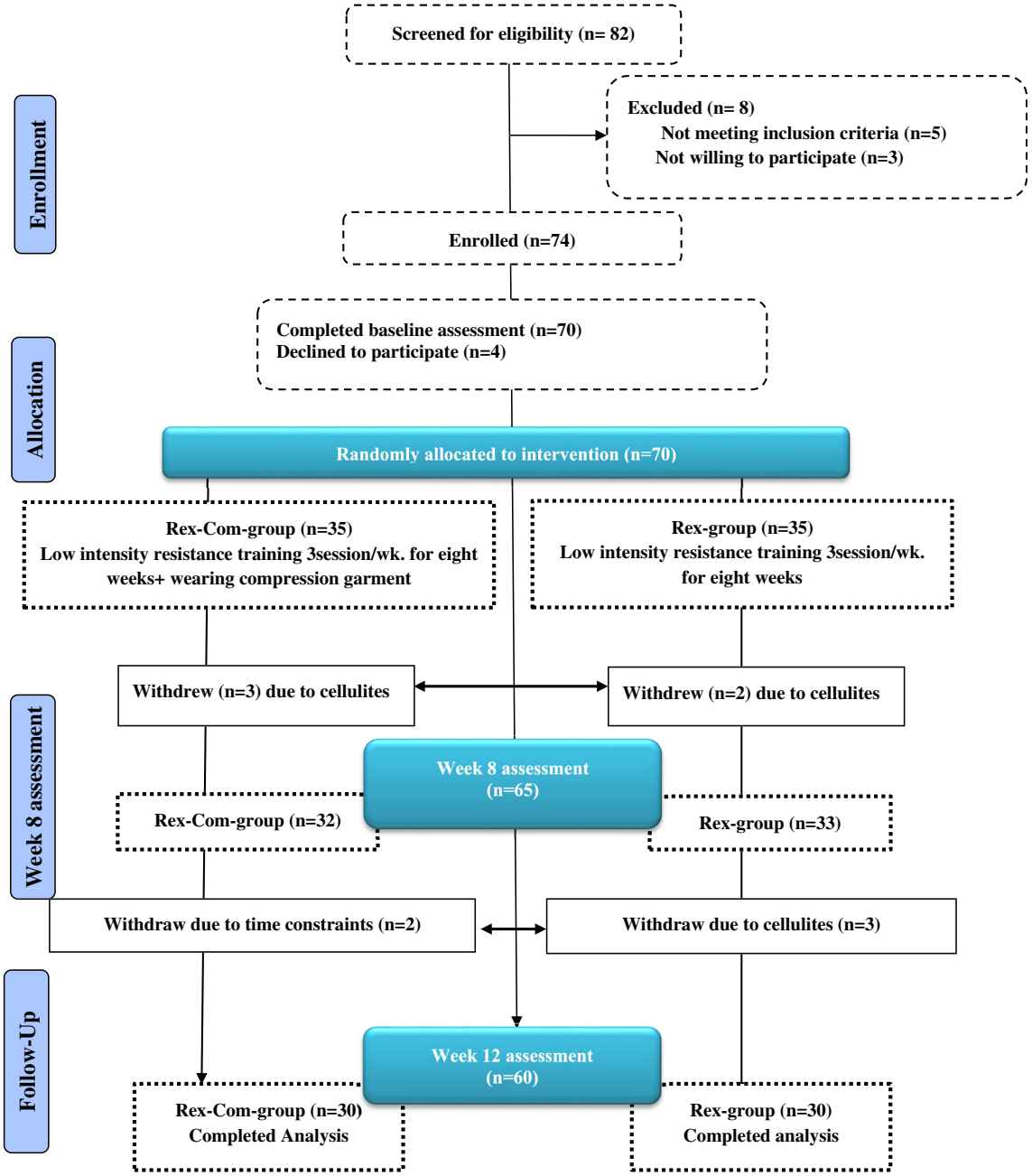

Fig. 1 Participant flow through the intervention and data collection to final analysis

not statistically significant when compared with changes at the end of treatment (W8) in both the groups (Rex-Comp group 21.00 ± 11.48; Rex group 23.24 ± 13.87; $p > 0.05$). There were no differences between the groups concerning DASH scores between the groups at the end of the treatment ($p = 0.63$) or at follow-up ($p = 46$).

Adherence Rate

Self-reported adherence was completed and returned by 93.33% ($n = 56$) of the participants: 96.67% ($n = 29$) in the Rex-Com group and 90% ($n = 27$) in the Rex group. Of those, 53 participants attended at least 92% supervised exercises session (Rex-Com-group ($n = 27$) and Rex group ($n = 26$)), with no statistically significant difference between both groups ($p > 0.05$). The rate of adherence for wearing compression garment was 92% in the Rex-Com group (range 84 to 100%).

Discussion

The results revealed that low-intensity resistance exercises for 8 weeks irrespective of garment use resulted in a reduction in lymphedema volume, and self-reported sensation of pain,

Table 1 Baseline demographic and clinical characteristics of participants

	Rex-Com group ($n = 30$)	Rex group ($n = 30$)	p value
Age (years)	53.78 ± 2.99	52.62 ± 2.92	0.12*
BMI(kg/cm^2)	30.23 ± 4.81	29.85 ± 4.75	0.55*
Affected arm, right/left *n* (%)	21 (70%)/9 (30%)	18 (60%)/12 (40%)	0.35
Educational level *n* (%)			
Illiterate	7 (23.33%)	8 (26.67%)	0.69
Low education	12 (40%)	13 (43.33%)	
University degree	11 (36.67%)	9 (30%)	
Occupation *n* (%)			
Housewife	18 (60%)	21 (70%)	0.79
Office worker	12 (40%)	9 (30%)	
Menstrual status *n* (%)			
Premenopausal	10 (33.33%)	12 (40%)	0.73
Postmenopausal	20 (66.67%)	18 (60%)	
Surgical intervention			
Lumpectomy + ALND	8 (26.67%)	7 (23.33%)	0.9
MRM	10 (33.33%)	11 (36.67%)	0.93
SNB + ALND	12 (40%)	12 (40%)	0.93
Number of lymph nodes removed	13.30 ± 3.60	15.30 ± 4.60	0.67*
Number of positive lymph nodes	3.50 ± 0.30	5.3 ± 0.50	0.93*
Adjuvant therapy *n* (%)			
Radiotherapy	15 (50%)	12 (40%)	0.80
Chemotherapy	12 (40%)	12 (40%)	0.79
Hormonal therapy	10 (33.33%)	9 (10%)	0.88
Time since surgery(years)	6.15 ± 1.39*	6.75 ± 2.25	0.30*
Duration of lymphedema (months)	12.73 ± 5.61*	11.83 ± 5.02	0.69
Stage of lymphedema			
I	22 (73.33%)	21 (70%)	0.38
II	6 (20%)	6 (20%)	
III	2 (6.67%)	3 (10%)	
Severity of lymphedema			0.27
Mild	20 (66.67%)	18 (60%)	
Moderate	10 (33.33%)	12 (40%)	

Data presented as mean and standard deviation unless otherwise indicated

Rex group, exercises group; Rex-Com group, exercises plus compression garment group

ALND axillary lymph node dissection, *MRM* modified radical mastectomy, *SNB* sentinel lymph node biopsy

*p values non-significant ($p > 0.05$) between groups

p values non-significant ($p > 0.05$) between groups (chi-square test)

heaviness, and tightness, and an increase in shoulder mobility and upper limb function. So, these results add to the knowledge that exercise is beneficial for BCRL and does not aggravate lymphedema and favor lymphedema volume reduction irrespective of garment use.

The findings from the current study are in line with previous studies that reported no exacerbation of lymphedema during resistance exercises irrespective of garment use [31–35, 52]. Recent work of Sing et al. [31] reported a reduction in the severity of lymphedema symptoms by half after 12 weeks of home-based exercises including both aerobic and resistance exercises, of moderate intensity irrespective of garment usage. Moreover, Sing et al. [32] concluded that there was no exacerbation of subjective symptoms following a single bout of moderate-load upper body resistance exercises. The results are in agreement with a finding of early work by Johansson et al. [52], which showed a reduction in subjective symptoms of heaviness and tension at 24 h following the acute bout of moderate-load exercises without a compression garment. Another study by Schmitz et al. [19] showed improvement

Table 2 Lymphedema volume from baseline (W0) to follow-up assessment (W12) by intervention groups

	W0 Baseline		W8 End of treatment		W12 Follow-up	
	Rex group ($n = 26$)	Rex-Com group ($n = 28$)	Rex group ($n = 26$)	Rex-Com group ($n = 28$)	Rex group ($n = 26$)	Rex-Com group ($n = 28$)
ELV(ml)	479.98 ± 127.55*	489.92 ± 172.55	434.99 ± 121.27*,	437.12 ± 170.92	429.07 ± 119.85*, φ	426.73 ± 167.31 φ
% ELV	20.64 ± 5.17*	21.29 ± 8.30	18.71 ± 5.01*,	18.99 ± 8.15	18.45 ± 4.86*, φ	18.54 ± 7.96 φ
Changes in ELV	–	–	44.99 ± 23.55*,	52.80 ± 37.65	50.91 ± 29.711*, φ	63.19 ± 41.85 φ
% Reduction ELV	–	–	9.37 ± 4.54*,	10.77 ± 7.36	10.61 ± 3.54*, φ	12.89 ± 8.23 φ

Data presented as mean and standard deviation unless otherwise indicated

Rex group, exercises group; Rex-Com group, exercises plus compression garment group

ELV excess limb volume

*Non-significant ($p > 0.05$) between groups at baseline (W0), at end of treatment (W8), and at follow-up (W12)

, Significant ($p < 0.05$) within groups at the end of treatment (W8) and follow-up (W12) compared with baseline (W0)

φ Non-significant ($p > 0.05$) within groups at follow-up assessment (W12) compared with postintervention (W0)

in symptoms severity and a low rate of exacerbations after 12 months of the resistance exercise program plus the application of the compression garment during exercising. In addition, an early work of Kim et al. [50] and a recent study by Bok et al. [51] found that progressive resistance exercises plus complete decongestive physical therapy including compression garment did not cause exacerbations of lymphedema, and arm volume reduced as manifested by decreased circumferences and subcutaneous tissue thickness and increased muscles thickness.

Despite these similarities in findings, the exercises intervention differed and comprised several modes: resistance exercises alone [19, 24, 32, 50, 51], aerobic exercises, or both [20, 31]. There is great variation in exercise intensity, repetitions, set, duration and frequency; acute, and single bout versus chronic multiple session exercises [19, 24, 31, 32, 50, 51]. There is great variability related to the definition and severity of lymphedema and the time of lymphedema assessment during and after the exercise interventions [31–35, 50, 51]. In addition, there is diversity in arm volume measurement including circumference measurements [24, 31, 32, 35, 51, 50], water displacement [19], bioimpedance [20, 24, 31, 32], perometry [20, 21], and dual X-ray [24], regarding the use of compression garments. The national lymphedema networks

Table 3 Comparison of changes in self-reported lymphedema symptoms and shoulder mobility and function at baseline (W0) and follow-up assessment (W12) by intervention groups

Variables	W0 Baseline		W8 End of treatment		W12 Follow-up	
	Rex group ($n = 26$)	Rex-Com group ($n = 28$)	Rex group ($n = 26$)	Rex-Com group ($n = 28$)	Rex group ($n = 26$)	Rex-Com group ($n = 28$)
Self-reported lymphedema symptoms						
Pain	5.80 ± 2.90*	5.20 ± 2.75	4.92 ± 5.05*,	4.75 ± 3.60	4.75 ± 3.60*, φ	4.50 ± 2.05 φ
Heaviness	6.90 ± 4.14*	6.50 ± 3.50	5.05 ± 3.94*,	4.89 ± 3.35	5.05 ± 3.94*, φ	4.78 ± 3.35 φ
Tightness	6.80 ± 4.60*	6.25 ± 5.60	5.35 ± 4.95*,	5.25 ± 4.75	4.92 ± 4.75*, φ	4.75 ± 4.05 φ
Shoulder ROM/function						
Flexion	125.60 ± 7.20*	129.40 ± 6.20	141.90 ± 8.60*,	145.50 ± 9.60	151.40. ± 14.70*, φ	155.75 ± 11.37 φ
Abduction	109.30 ± 10.50*	107.40 ± 19.8	120.50 ± 9.30*,	125.21 ± 8.30	129.50 ± 13.80*, φ	133.60 ± 10.20 φ
External rotation	51.20 ± 7.40*	49.90 ± 6.50	56.30 ± 8.50*,	59.50 ± 7.83	63.50 ± 7.87*, φ	69.60 ± 6.39 φ
DASH scores	29.67 ± 15.19*	27.65 ± 13.64	23.24 ± 13.87*,	21.00 ± 11.48	22.24 ± 11.87*, φ	20.83 ± 12.48 φ

Data presented as mean and standard deviation unless otherwise indicated

Rex group, exercises group; Rex-Com group, exercises plus compression garment group

*Non-significant ($p > 0.05$) between groups at baseline (W0), at end of treatment (W8), and at follow-up (W12)

, Significant ($p < 0.05$) within groups at the end of treatment (W8) and follow-up (W12) compared with baseline (W0)

φ Non-significant ($p > 0.05$) within groups at follow-up assessment (W12) compared with postintervention (W0)

medical advisory committee recommended the use of the garments for participants suffering from lymphedema in particular those with BCRL. This advice was considered in several studies [19, 50, 51], while in another study, the participants were free to choose whether to wear a compression garment during the exercises session or not [24, 20].

The underlying mechanisms behind the use of low-intensity progressive resistance exercise training along with compression garment to reduce lymphedema volume and symptoms include the enhancement of venous and lymphatic flow [16, 53, 54], and improved protein resorption [55]. Exercising regulates and controls sympathetic nerves resulting in self-contraction of the lymphatic vessels, which is important for the long-term management of lymphedema [53, 54]. Also, stretching exercises may help reduce the soft tissue contractures and, hence, decrease the blood and lymphatic obstruction [56], and decrease the tension on free nerve ending with subsequent improvement in pain perception and tightness of the surrounding tissues [31]. Using a compression garment during exercises creates counterforce that helps in lymphatic drainage and limits vascular permeability affected by vascular pressure [51]. Using compression may enhance local blood circulation and reduce the magnitude of inflammation associated with swelling, and perception of pain, and reduction of blood lactate concentrations. In addition, it facilitates the clearance of lactate, myocellular proteins, and inflammatory mediators, which reduce the effects of delayed onset muscle soreness following exercise [57]. These may consider desirable for patients with an impaired lymphatic system, such as those with lymphedema.

One of the major strength of the current study is the higher rate of adherence to exercises attendance (93% of the training sessions). The rate of adherence to the garment use is high (92%) and only a few women reported intolerance to garment and discomfort, despite difficulties associated with applying and removing the garment. These rate of adherence is higher than those reported in the previous work of Gautam et al. [56], Ahmed et al. [58], and Schmitz et al. [19] who reported an 89%, 80%, and 88% adherence rate to an 8-week exercises program, twice a week supervised exercises program for 6 months, and 1 year. The adherence rate of the current study is higher compared with the previous work by Boris et al., who reported a 52% adherence for wearing a compression garment day and night, and performing the exercises twice a day [59], and Vignes and Porcher who reported adherence of 74% for a low-stretch bandages protocol and 90% for an elastic sleeve wearing protocol [60]. This higher rate of adherence may be attributed to a short period of exercises program (8 weeks). Also, supervised exercises provided feedback and instructions that help women to maintain good adherence. Along with that, a blinded therapist conducted all measurements over the study period.

This study has several drawbacks. One major limitation was that most recruited women had mild lymphedema (63.3%) and with most of them had stage I lymphedema (71.67%). Therefore, further consideration should include women with moderate and severe lymphedema. Inclusion of mild lymphedema with only one segment of the limb is > 10% larger than the contralateral limb is necessary. These will increase both generalizability and the rate of recruitment. Another limitation was that the measurement of limb volume was performed using circumference methods only. This method is reliable and valid [19, 52, 53]. However, it is not sensitive to detect changes in the intracellular/extracellular tissue fluid secondary to exercises and use of the garment. So we recommend conduction of further study using either bioimpedance spectroscopy or ultrasonography as non-invasive methods to detect changes in the tissue fluid and thickness.

Conclusion

It is suggested that low-intensity resistance training irrespective of garment use was found to improve effectively the affected limb volume and lymphedema associated symptoms, coupled with improvement in shoulder mobility and function. These desirable effects could be continued for a duration of 12 weeks. These positive effects may have a significant clinical impact such as a therapist can safely describe low-intensity exercises for women with BCRL. In addition, once the lymphedema patient adheres to the recommended exercise program, there will be a reduced risk of increased limb volume and developed complication such as functional impairment and discomfort.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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